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Energy Efficient Routing in Zigbee Wireless Sensor Network- A Review

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Abstract: As we distinguish, the data communication in the wireless networks is more untrustworthy than it is in the wired network environment. Even though the virtual carrier sensing scheme can be used in the wireless unicast transmission, the multicast and broadcast still not exploit the acknowledgement instrument for reliable transmission. This is due to the acknowledgement packets of broadcast programme will cause much sophisticated communication traffic and overhead. Since reliable data broadcast is critical and obligatory in many applications in the wireless sensor networks, our study focuses on the ZigBee network which is a new industrial standard for sensor networks. Some previous related papers improved the broadcast reliability by introducing redundant transmission and increasing coverage ratio of every receiver node, but there still exists probability of packet loss and extra communication cost due to redundant broadcast. Wireless sensor networks are functioning in several applications, including military, medical, environmental and domestic. In all these applications, energy usage is the determining factor in the performance of wire- less sensor networks. As a result, methods of zigbee based data routing and transferring to the base station are very important because the sensor nodes run on battery power and the energy available for sensors is limited. This Paper reviews all the aspects and constraints related to data routing within zigbee wireless sensor network.

Keywords: Zigbee Specifications, wireless sensor network, cluster based routing, energy efficiency, IEEE 802.15.4.

I. INTRODUCTION

Wireless sensor networks, an emerging technology are made up of sensor nodes which are distributed and autonomous in nature. These sensor nodes can vary in number from a few to thousands depending on the situation in which they are being used. These sensor networks are used in military, monitoring applications etc. they are also used in hostile environments such as disaster struck areas. Depending on the application or the area in which such a network is used the energy utilization of the individual nodes can vary.

Wireless Sensor Network (WSN) is usually deployed with a great number of sensor nodes to cover a large range of area to monitor events, collect data from environment, etc. The data collected by sensor nodes is usually transmitted to sink nodes, which are gateways to outside world, for further processing by a multi-hop network. Node failures and relocations should not hinder the successful transmission of data to the sinks. Consequently, WSN needs to be capable of adapting to changes in network topology caused by node failures, relocations and so on.

Initially, research interest is focused on single sink WSN [1] and [2]. However, scalability of single sink WSN is not good enough to satisfy the demand of transmitting data from a large number of nodes to a single sink. As the number of nodes increases, network congestion due to hot spot phenomenon will be so severe that transmission cannot continue. Recently, interest is changed toward to multi-sink WSN [3]-[5]. In a multi-sink WSN, the mean number of hops between nodes and sinks can be reduced remarkably; network congestion can be relieved by using appropriate routing method to balance traffic load among the sinks evenly.

ZigBee is a specification of high level communication protocols built on top of IEEE 802.15.4 standard. Because of its low cost low power consumption properties and ability to support mesh network topology, zigbee is an ideal technology for implementation of WSN.

ZigBee [6] is a wireless “standard” of ZigBee alliance based on IEEE 802.15.4 standard [7] for Personal Area Networks. It defines the network and application layers on the top of physical and data link layers normalized in IEEE 802.15.4. ZigBee stack offers a wireless communication solution coupled with low cost, low energy consumption characteristics. It can be used in consumer electronics, industrial controls, PC peripherals, toys and games, etc. However, one of the potential applications of this standard is in Wireless Sensor Networks (WSN). In fact, IEEE 802.15.4 is designed to achieve a very low power consumption through several optimizations in Physical layer and Medium Access Control (MAC) sub-layer like the use of low duty cycles. The network layer uses a modified AODV (Ad Hoc on Demand Distance Vector) by default and Hierarchical Tree Routing (HTR) as last resort.

WSN have focused on Quality of Service (QoS) support to improve the reliability and performance under severe energy constraints. The improvement of QoS can be tackled in any layer. For instance several research work has been carried out on improving real time support in MAC sub-layer using GTS (Guaranteed Time Slot) mechanism of IEEE 802.15.4 [8]. This improves only real time QoS in single hop networks. In network layer, which provides end to end real time QoS in multi hop networks, this is done by adding and improving the QoS support to the routing algorithm. However, before doing that we need

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to analyze the performance of the existing routing algorithms. It is clear that our aim in long term is to provide real time support in ZigBee Routing Protocol (ZRP).

A. Background of ZigBee

The ZigBee specification identifies three kinds of devices that incorporate ZigBee radios, with all three found in a typical ZigBee network:

- A coordinator, which organizes the network and maintains routing table.
- Routers, which can also have the routing capacity for maintaining routes and talk to all kinds of devices.
- End devices, which can talk to routers and the coordinator, but not to each other.

The ZigBee mesh routing adopts the well-studied public domain algorithm AODV [9]. As AODV is a pure on-demand protocol, route discovery is based on a route request and route reply query cycle. Route discovery begins when a source node desires to send data to some destination.

As shown in Figure 1, the source node first broadcasts a route request (RREQ) packet to its neighbours. When a node receives the RREQ, it then checks whether it has an unexpired route to the destination node. If not, it creates a route entry and a route discovery entry. The information stored in the route entry includes *destination address*, *status*, and *next-hop address*. Next, the route discovery entry contains *Route Request ID*, *Source Address*, *SenderAddress*, *Forward Cost*, *Residual Cost*, and *ExpirationTime*. The Route Request ID is incremented for every RREQ the node initiates, and together with the source address, uniquely identifies a RREQ.

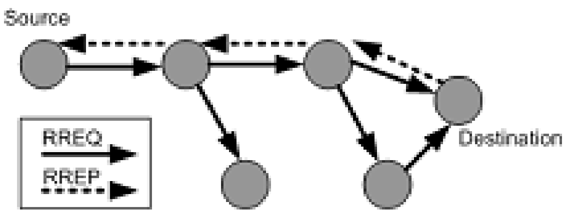

Figure 1: Basic routing discovery

Along with its own sequence number and the Route Request ID, the source node includes in the RREQ the most recent sequence number it has for the destination. In order to respond to the RREQ, the node must be the destination itself. If neither of this condition is met, the node rebroadcasts the RREQ.

The latest ZigBee specification, officially named ZigBee 2012, offers full wireless mesh networking capable of supporting more than 64,000 devices on a single network. It's designed to connect the widest range of devices, in any industry, into a single control network. ZigBee supports the largest number of interoperable standards including ZigBee Building Automation, ZigBee Health Care, ZigBee Home Automation, ZigBee Light Link, ZigBee Smart Energy, ZigBee Telecom Services, and the forthcoming ZigBee Retail Services.

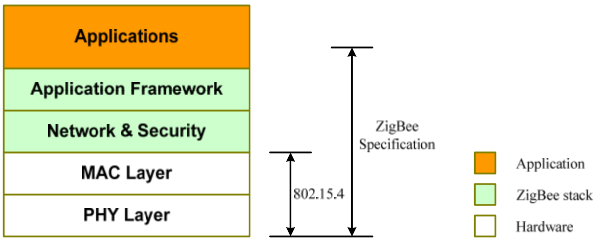

Figure 2. The ZigBee/IEEE 802.15.4 protocol stack.

II. ROUTING IN WIRELESS NETWORK

Routing is the act of moving information across an inter-network from a source to a destination. Along the way, at least one intermediate node typically is encountered. It's also referred to as the process of choosing a path over which to send the packets. Routing is often contrasted with bridging, which might seem to accomplish precisely the same thing to the casual observer. The primary difference between the two is that bridging occurs at Layer 2 (the data link layer) of the OSI reference model, whereas routing occurs at Layer 3 (the network layer). This distinction provides routing and bridging with different information to use in the process of moving information from source to destination, so the two functions accomplish their tasks in different ways. The routing algorithm is the part of the network layer software responsible for deciding which output line an incoming packet should be transmitted on, i.e. what should be the next intermediate node for the packet.

Routing protocols use metrics to evaluate what path will be the best for a packet to travel. A metric is a standard of measurement; such as path bandwidth, reliability, delay, current load on that path etc; that is used by routing algorithms to determine the optimal path to a destination. To aid the process of path determination, routing algorithms initialize and maintain routing tables, which contain route information. Route information varies depending on the routing algorithm used.

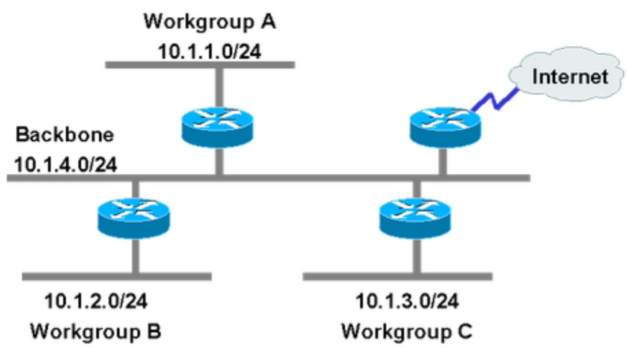

Figure 3: Typical router-based campus network

Desirable properties of a router are as follows:

- Correctness and simplicity
- Robustness
- Stability
- Fairness and optimality
- Efficiency

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III. CLASSIFICATION OF WIRELESS SENSOR NETWORKS

According to a new report from research firm ON World "The home market for Wireless Sensor Networks (WSN) will reach US$6 billion a year by 2012". The prediction includes both products and services centred on in-home energy management and health monitoring. Meanwhile, ON World predicts the market for "Home Area Network" (HAN) energy management solutions to reach 20 million homes worldwide by 2013.

Wireless Sensor Networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar. They are able to monitor a wide variety of ambient conditions that include temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, the presence or absenceof certain kinds of objects, mechanical stress levels on attached objects, and the current characteristics such as speed, direction and size of an object. WSN applications can be classified into two categories [10] as shown in Figure 3:

- Monitoring
- Tracking

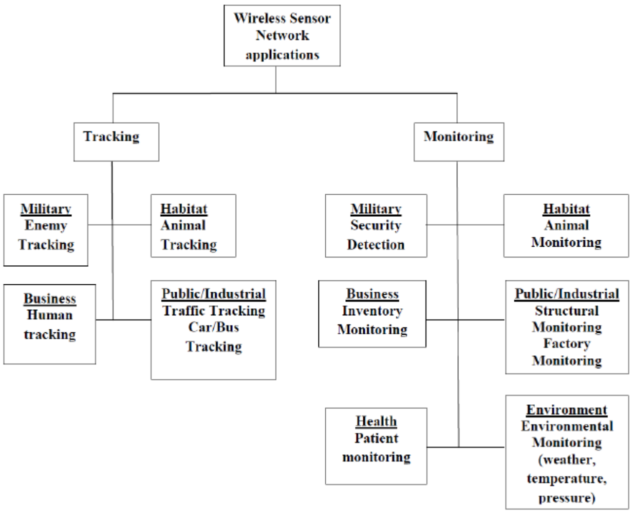

Figure 4: Overview of Wireless Sensor Network applications [10]

Monitoring applications include indoor/outdoor environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications include tracking objects, animals, humans, and vehicles and categorize the applications into military, environment, health, home and other commercial areas. It is possible to expand this classification with more categories such as space exploration, chemical processing and disaster relief.

In this subdivision a simple classification of the sensor networks based on their mode of the functioning & the type of target application is obtainable and are proactive, reactive, and hybrid networks.

IV. REVIEW OF LITERATURE

In 1981, Baker and Ephremides proposed a clustering algorithms called —Linked cluster algorithm (LCA) [20] for wireless networks. To enhance network manageability, channel efficiency and energy economy of MANETS, Clustering algorithms have been investigated in the past. Lin and Gerla investigated effective techniques to support multimedia applications in the general multi-hop mobile ad-hoc networks using CDMA based medium arbitration in [21]. Random competition based clustering (RCC) [22] is applicable both to mobile ad hoc networks and WSN. RCC mainly focuses at cluster stability in order to support mobile nodes. The RCC algorithm applies the First Declaration Wins rule, in which any node can "govern" the rest of the nodes in its radio coverage if it is the first to claim being a CH. Some of well-known clustering algorithms for mobile ad hoc networks presented in the literature are Cluster Gateway Switch Routing Protocol (CGSR) [23], Cluster-Based Routing Protocol (CBRP) [24], Weighted Clustering Algorithm (WCA) [25]. A survey of clustering algorithms for mobile ad hoc networks has been discussed in [26].

In recent years, insect sensory systems have been inspirational to new communications and computing models like bio inspired routing. It is due to their ability to support features like autonomous, and self-organized adaptive communication systems for pervasive environments like WSN and mobile ad hoc networks. Biological synchronization phenomena have great potential to enable distributed and scalable synchronization algorithms for WSN [27]. The first MANET routing algorithm in the literature to take inspiration from ants are Ant-Colony Based Routing Algorithm (ARA) [28], AntNet [29], AntHocNet [30] etc. In [31], an energy efficient and delay-aware routing algorithm is proposed based on ant-colony-based algorithms. In [32], a bio-inspired scalable network synchronization protocol for large scale sensor networks is proposed, which is inspired by the simple synchronization strategies in biological phenomena such as flashing fireflies and spiking of neurons. A biologically inspired distributed synchronization algorithm introduced in [33] is based on a mathematical model. It explains how neurons and fireflies spontaneously synchronize. In [34], the principles of genetics and evolution are adopted to enable service-oriented, autonomous, and self-adaptive communication systems for pervasive environments such as WSN and mobile ad hoc networks. In [35], efficient bio-inspired communication paradigm for WSN is proposed based on the feedback loop mechanism developed by inspiration from the principles of cell biology. In [36], a clustering algorithm based on biological quorum sensing mechanism is mentioned. It helps the sensor nodes to form clusters according to spatial characteristics of the observed event signal.

QoS is the ability of a network element (e.g. an application, host or router) to have some level of assurance that its traffic and service requirements can be satisfied. QoS manages bandwidth according to application demands and network management settings. QoS has been extensively studied in wireless LANs and wired computer networks. IP and Asynchronous Transfer Mode (ATM)

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provide extensive QoS support ranging from best-effort service to guaranteed service.

A comprehensive overview of the state of the field of QoS in networking was provided by Chen in his thesis in 1999 [37]. Chakrabarti and Mishra [38] summarized the important QoS-related issues in MANETs and the future work that required further attention is provided in [39]. In 2004, Al-Karaki and Kamal [40] presented a detailed overview about the state of and the development trends in the field of QoS. It categorized routing into the following types of approaches: flat (all nodes play an equal role), hierarchical (some nodes are local cluster heads for example), position based (utilize location information), and power-aware (take battery usage and residual charge into consideration) QoS routing. Finally, a detailed overview of the more widely accepted MAC and routing solutions for providing better QoS was presented in [41,42].

In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure. In flat-based routing, all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network.

A routing protocol is considered adaptive if certain system parameters can be controlled in order to adapt to the current network conditions and available energy levels. Furthermore, these protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, or routing techniques depending on the protocol operation. In addition to the above, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source sends a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. When sensor nodes are static, it is preferable to have table driven routing protocols rather than using reactive protocols. A significant amount of energy is used in route discovery and setup of reactive protocols. Another class of routing protocols is called the cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy usage.

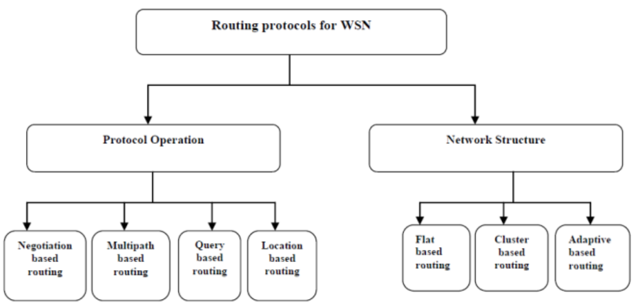

Figure 5: Taxonomy of routing protocols for WSN

1. THE ROUTING PROTOCOLS FOR PROTOCOL OPERATION

Negotiation based routing: These protocols use high-level data descriptors called ―meta-data‖ in order to eliminate redundant data transmission through negotiations. The necessary decisions are based on available resources and local interactions.

Sensor Protocols for Information via Negotiation (SPIN) [43] is one of well-known Negotiation based routing protocol for WSN. The SPIN protocols are designed to disseminate the data of one sensor to all other sensors assuming these sensors are potential base-stations. Hence, the main idea of negotiation based routing in WSN is to suppress duplicate information and prevent redundant data from being sent to the next sensor or the base-station by conducting a series of negotiation messages before the real data transmission begins.

Multipath based routing: These protocols offer fault tolerance by having at least one alternate path (from source to sink) and thus, increasing energy consumption and traffic generation. These paths are kept alive by sending periodic messages.

Maximum Lifetime Routing in Wireless Sensor Networks [44] is a protocol that routes data through a path whose nodes have the largest residual energy. The path is switched whenever a better path is discovered. The primary path will be used until its energy is below the energy of the backup path. By means of this approach, the nodes in the primary path will not deplete their energy resources through continual use of the same route, thus achieving longer lifetime. A disadvantage for applications that require mobility on the nodes, is that the protocol is oriented to solve routing problem in static wireless networks.

Query based routing: In these protocols, the destination nodes propagate a query for data (sensing task or interest) from the node through the network. The nodes containing this data send it back to the node that has initiated the query.

Rumor routing protocol [45] is one of the routing protocol used in the context of event notification. The approach does not flood the network with information about an event occurrence but only installs few paths in the network by sending out one or several agents. The agents propagate through the network installing routing information about the event in each node that is visited. When the agents come across shorter paths or more efficient paths, they optimize the paths in the routing tables accordingly. Each node can also generate an agent in a probabilistic fashion.

Location based routing: In the protocols, the nodes are addressed by their location. Distances to next neighbouring nodes can be estimated by signal strengths or by GPS receivers.

Location based routing protocols are: .Small Minimum Energy Communication Network (SMECN) [46] protocol sets up and maintains a minimum energy network for wireless networks by utilizing low power GPS. Although, the protocol assumes a mobile network, it is best applicable to sensor networks, which are not mobile.

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Geographic Adaptive Fidelity (GAF) [47] protocol is energy-aware location-based routing designed primarily for mobile ad hoc networks and can be applicable to sensor networks as well. GAF keeps energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. Such equivalence is exploited in keeping some nodes located in a particular grid area in sleeping state in order to save energy. Thus, GAF can substantially increase the network lifetime as the number of nodes increase. GAF protocol has both for non-mobility (GAFbasic) and for mobility (GAF-mobility adaptation) of nodes.
Geographic and Energy Aware Routing (GEAR) [48] is the protocol which uses geographic information while disseminating the queries to the areas of interest since data queries often includes geographic attributes. The protocol uses energy aware and geographically informed neighbour selection to route a packet towards the target area. GEAR can complement directed diffusion by restricting the number of interests sent, and only considering a certain area rather than sending the interests to the whole network. In GEAR, each node keeps an estimated cost and a learning cost of reaching the destination through its neighbours.Avirtual relative position based routing protocol for sensor networks that provides methods for data management is Virtual Cord Protocol (VCP) [49]. VCP is a Distributed Hash Table like protocol that offers an efficient routing mechanism, besides standard DHT functions. The key characteristics of VCP are the geographical vicinity of virtual neighbors, which reduces the communication load.

2. ROUTING IN ZIGBEE TOPOLOGY

In a tree network, the ZigBee coordinator and routers can transmit beacons. Sending beacons facilitates devices to synchronize with their parents and thus can support devices to go to sleep and save energy. Recall that after forming a network, the network coordinator will determine the beacon order (BO) and superframe order (SO). When BO is larger than SO, devices can go to sleep during the inactive portions of superframes. In the ZigBee network specification version 1.0, a superframe can be divided into 2BO-SO non-overlapping time slots. A router can choose a slot to announce its beacon. The start time of its beacons is also the start time of superframes of that router. Therefore, routers' superframes will be shifted away from those of the coordinator's by multiples of SD.
To avoid collisions, a device should not arbitrarily choose a slot to transmit its beacons. A device should avoid using the same beacon transmit slots as its neighbors' and its parent's; otherwise, its children may lose beacons due to collisions. Beacon collisions may occur in two ways: direct beacon conflict between two neighbors and indirect beacon conflict between non-neighbors. Since A and B are not neighbors, the conflict is more difficult to detect. The ZigBee network specification version 1.0 does not provide an explicit solution to this problem. In the current specification, a device should keep the beacon transmission schedules of its neighbors and its neighbor's parents. In other words, beacon transmission schedules of nodes within two hops should be maintained. The same slots should be avoided. When sending beacons, a device will add the time offset between its beacon transmission time and its parent's in the beacon payload. This will help a device to choose a conflict-free slot.
In a tree network, a device decides its beacon transmission time when joining the network. During the joining procedure, a device listens to the beacons from its parent and its neighbors for a period of time. Then the device calculates an empty slot as its beacon transmission slot. If there is no available slot, this device will join this network as an end device. After deciding beacon transmission time, the network layer will inform the MAC layer the time difference between its beacon transmission time and its associated parent's beacon transmission time.

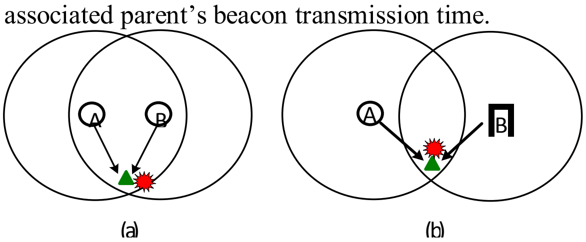

Figure 6: Beacon conflicts in a ZigBee tree network: (a) direct beacon conflict and (b) indirect beacon conflict.
The ZigBee network specification version 1.0 defines the broadcast procedure in mesh networks. The network layer informs the MAC layer to broadcast network-layer packets. In ZigBee, the broadcast initiator can specify the scope of this broadcast. A device that receives a broadcast packet will check whether the radius field in the broadcast packet is larger than zero. If so, the device will rebroadcast the packet; otherwise, this packet will not be further broadcast. ZigBee defines a passive acknowledgement mechanism to ensure the reliability of broadcasting. After broadcasting, the ZigBee device records the sent broadcast packet in its broadcast transaction table (BTT). The BTT will be combined with its neighbor table. This allows devices to track whether their broadcast packets have been properly rebroadcast or not. If a device finds that a neighbor does not rebroadcast, it will rebroadcast to guarantee reliability.
In ZigBee, devices use different strategies to broadcast packets according to the parameter $maxRxOnWhenIdle$ in the MAC layer. $maxRxOnWhenIdle$ controls whether a device can receive data when idle. By the nature of wireless communication, devices can detect radio signals when idle. However, they will refuse to process the received signals if $maxRxOnWhenIdle$ is False. When broadcasting is needed, a device with $maxRxOnWhenIdle$ = True will do so immediately. This device will also unicast the broadcast packet to those neighbors with $macRxOnWhenIdle$ set to False. On the other hand, a device with $macRxOnWhenIdle$ set to False can only unicast the broadcast packet to its neighbors. This is because that the device may miss passive acknowledgements from neighbors. Unicasting

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can ensure reliability. Fig. x. 12 shows an example that router A sets *macRxOnWhenIdle* to False. After receiving the broadcast packet from S, A will relay the packet to B and C by unicasting. However, broadcasting in ZigBee network may cause redundant transmissions. Reference (Ding et al., 2006) introduces a tree-based broadcast scheme to relieve this problem. The authors utilize the properties of ZigBee address assignment to find a set of forwarding nodes in the network. The proposed algorithm incurs low computation cost.

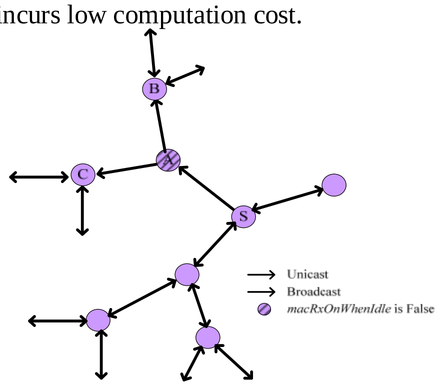

Figure 7: A broadcast example in a ZigBee Network.

At the beginning of a route discovery, the source broadcasts a route request packet. A ZigBee router that receives a route request packet first computes the link cost. If this device has routing capacity, it will rebroadcast this request if it does not receive this request before or the link cost recorded in route request plus the cost it just computed is lower than the former received request. Otherwise, it will discard this request. For the case that a ZigBee router that is not routing capable receives a route request, it also determines whether to resend this request based on the same comparison. If this device determines to resend this route request, it will check the destination address and unicast this route request to its parent or to one of its children (in the tree network). Device S broadcasts a route request for destination T and devices A and D receive this packet. Since device A has no routing capacity, it will check the address of destination T and unicast this request to device C. Since device D has routing capacity, it will rebroadcast this request. A device that has resent a route request packet will record the request sender in its route discovery table. This information will be discarded if this device does not receive a route reply within a time interval.

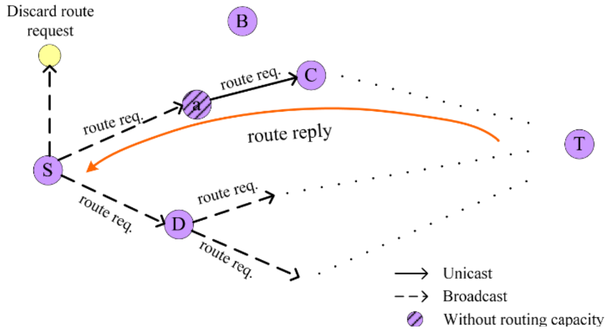

Figure 8. An example of route request dissemination in a ZigBee network.

When the destination receives route request packets from multiple paths, it will choose the routing path with the lowest cost and send a route reply packet to the source. The route reply packet will be sent by unicast. An intermediate node that receives the route reply packet checks its route discovery table and sends the route reply to the request sender. After the source node successfully receives the route reply, it can send data packets to the destination node along the discovered route.

The ZigBee network layer also specifies route maintenance mechanisms for mesh and tree networks. In a mesh network, route failure is detected by a failure counter. If the counter of a ZigBee router exceeds a threshold, the router can start the route maintenance procedure. For those routers that have routing capacity, they can flood route request packets to find destinations. For routers that do not have routing capacity, they will unicast route request packets to their parents or children according to the destination addresses. However, in a tree network, a router does not broadcast route request packets when it loses its parent. Instead, it disassociates with its parent and tries to re-associate with a new parent. After re-association, it will receive a new short 16-bit network address and can transmit packets to its new parent.

3. THE ROUTING PROTOCOLS FOR NETWORK STRUCTURE

Flat based routing: In these protocols, all nodes have assigned equal roles in the network. The well-known protocols considered in flat based routing are: Sequential Assignment Routing (SAR), .Directed Diffusion, Energy Aware Routing (EAR) etc.

Sequential Assignment Routing [50] proposed was one of the first protocols for WSN that considered QoS issues for routing decisions. The objective of SAR algorithm is to minimize the average weighted QoS metric throughout the lifetime of the network .SAR makes a routing decision based on three factors: energy resources, QoS planned for each path, and the packet‘s traffic type, which is implemented by a priority mechanism. To resolve reliability problems, SAR uses two systems consisting of a multipath approach and localized path restoration done by communicating with neighboring nodes. Although this ensures fault tolerance and easy recovery, the protocol suffers certain overhead when tables and node states must be maintained or refreshed. This problem increases especially when there are a large number of nodes.

Hierarchical based routing: It is also known as cluster-based routing. In these protocols, the nodes can play different roles in the network and normally the protocol includes the creation of clusters. Additionally, designations of tasks for the sensor nodes with different characteristics are also performed.

Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most popular clustering algorithms with distributed cluster formation for WSNs [51,52]. The algorithm randomly selects cluster heads and rotates the role to distribute the consumption of energy. LEACH uses TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions and data collection is centralized with

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defined periods. It forms clusters based on the received signal strength and uses the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability P and broadcasts its decision.

Adaptive based routing: In these protocols, the system parameters are controlled to be adapted to the actual network conditions by means of acquired information of the network and negotiation between nodes (e.g. the available energy on the node or QoS of the path).
Adaptive based routing is based on the family of protocols called Sensor Protocols for Information via Negotiation (SPIN) which is described in Negotiation based routing. The SPIN protocols are designed based on two basic ideas:

1. Sensor nodes operate more efficiently and conserve energy by sending metadata instead of sending all the data.
2. Flooding technique wastes energy and bandwidth when sending extra and unnecessary copies of data by sensors covering overlapping areas.

The protocols disseminate all the information at each node to every node in the network assuming that all nodes in network are potential base-stations. With this, the user can query any node and get the needed information immediately. The protocols use data negotiation and resource-adaptive algorithms. The nodes assign a high-level name to describe completely their collected data; this is called meta-data. Then are preformed negotiations before any data is transmitted to avoid redundant data to be transmitted. These protocols distribute the information all over the network, even when the user does not request any data.

Bio-inspired routing: In recent years insect sensory systems have been inspirational to new communications and computing paradigms, which have led to significant advances like bio inspired routing [53]. The most popular ACO (Ant Colony Optimization) is a colony of artificial ants is used to construct solutions guided by the pheromone trails and heuristic information they are not strong or very intelligent; but they successfully make the colony a highly organized society. Swarms are useful in many optimization problems. A swarm of agents is used in a stochastic algorithm to obtain near optimum solutions to complex, non-linear optimization problems [54].
Minimum Ant-based Data Fusion Tree (MADFT) [55] is a sink selection heuristic routing algorithm .It is based on ACO for gathering correlated data in WSN. It first assigns ants to source nodes. Then, the route is constructed by one of the ants in which other ants search the nearest point of previous discovered route. The chosen formula is Probability function composed of pheromones and costs in order to find the minimum total cost path. MADFT not only optimizes over both the transmission and fusion costs, but also adopts ant colony system to achieve the optimal solution.

V. CONCLUSION

In this paper, we have introduced the design of IEEE 802.15.4 and ZigBee network layer protocols. A lot of research institutes and industrial companies have developed their sensor platforms based on ZigBee/IEEE 802.15.4 solutions. ZigBee and IEEE 802.15.4 are designed for lightweight sensor platforms. We have also addressed some applications such as medical care and fire emergency applications and some prototyping systems. For further readings, (Intanagonwiwat et al., 2003; Schurgers and Srivastava, 2001) address routing protocols and (Dam and Langendoen, 2003; Gandham et al., 2005; Ye et al., 2002) discuss energy efficient MAC protocols in WSN**.**

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